NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

TECHNICAL NOTE

No. 1686

EFFECT OF LENGTH-BEAM RATIO ON AERODYNAMIC CHARACTERISTICS

OF FLYING-BOAT HULLS WITHOUT WING INTERFERENCE

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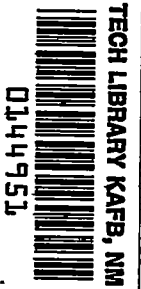OF FLYING-BOAT HULLS WITHOUT WING INTERFERENCE

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SUMMARY

An investigation was made to determine the effect of increasing
the length-beam ratio from 6 to 15 on the aerodynamic characteristics of
flying-boat hulls without wing interference. A comparison was made with
results obtained previously for hulls with wing interference reported
in NACA TN No. 1305.

An increase in the length-beam ratio decreased the minimum drag
coefficient and slightly increased the longitudinal stability in a manner
similar to that indicated for hulls with wing interference. As expected,
the hull-alone drag coefficients were consistently higher than the hull
drag coefficients with wing interference.

INTRODUCTION

The investigation at the Langley Laboratory of aerodynamic charac-
teristics of flying-boat hulls as affected by hull dimensions and hull
shape (references 1 and 2) has included the interference effects of a
21-percent-thick wing. Since new high-speed water-based airplanes will
probably use extremely thin wings of low aspect ratio and/or large
amounts of sweep, it was desirable to obtain the aerodynamic character-
istics of the aforementioned hulls without wing interference. The
results obtained for the hull without wing interference could be more
easily compared with either theoretical or experimental results for
other hull and fuselage shapes. The results obtained with wing
interference will differ from the values obtained for the hull or
fuselage alone because the wing, in addition to adding interference
drag, also effectively reduces the drag coefficient because of the
part of the wing submerged in the body (reference 3).

This paper presents the results of an investigation made to
determine the effect of length-beam ratio on the aerodynamic character-
istics of flying-boat hulls without wing interference. These results
are compared with previous results for hulls with wing interference.
The hulls have approximately the same hydrodynamic performance with
respect to spray and resistance characteristics, regardless of length-
beam ratio.

COEFFICIENTS AND SYMBOLS

The results of the tests are presented as standard NACA coefficients of forces and moments. Pitching moments are given about the locations shown in figure 1 which are the same as those used in reference 1. Therefore, a direct comparison of the longitudinal stability can be made with the hulls with wing interference. The coefficients and Reynolds number are based on the wing area and the mean aerodynamic chord of a hypothetical flying boat described in reference 1. The data are referred to the stability axes, which are a system of axes having the origin at the center of moments shown in figure 1 and in which the Z-axis is in the plane of symmetry and perpendicular to the relative wind, the X-axis is in the plane of symmetry and perpendicular to the Z-axis, and the Y-axis is perpendicular to the plane of symmetry. The positive directions of forces, moments, and angles are shown in figure 2.

The coefficients and symbols are defined as follows:

C_L lift coefficient (Lift/qS where Lift = $-Z$)

C_D drag coefficient (Drag/qS where Drag = $-X$ when $\psi = 0^\circ$)

C_m pitching-moment coefficient (M/qS$\bar{c}$)

M   pitching moment, foot-pounds

L'   rolling moment, foot-pounds

N   yawing moment, foot-pounds

X   force along X-axis, pounds

Y   force along Y-axis, pounds

Z   force along Z-axis, pounds

q   free-stream dynamic pressure, pounds per square foot $\left(\frac{1}{2}\rho V^2\right)$

S   wing area of $\frac{1}{10}$-scale model of hypothetical flying boat (18.264 sq ft)

$\bar{c}$ wing mean aerodynamic chord (M.A.C.) of $\frac{1}{10}$-scale model of hypothetical flying boat (1.377 ft)

V   air velocity, feet per second

ρ mass density of air, slugs per cubic foot

α angle of attack of hull base line, degrees

ψ angle of yaw, degrees

C_{D_W} drag coefficient, based on surface area W of hull (Drag/qW)

$$C_{m_\alpha} = \frac{\partial C_m}{\partial \alpha}$$

L/b   length–beam ratio, where L is distance from forward
                      perpendicular (F.P.) to sternpost and b is maximum
                      beam (fig. 1)

Subscript:

min   minimum

APPARATUS AND TESTS

The models used in this investigation were the same hulls that were
used in the investigation reported in reference 1. Dimensions of the
models are given in figure 1, and the offsets are given in tables I
to IV of reference 1. The models were altered for testing alone by
covering the wing gap with a thin sheet of aluminum. The volumes,
surface areas, maximum cross–sectional areas, and side areas of the
hulls are compared in the following table:

Langley tank model	L/b	Volume (cu in.)	Surface area (sq in.)	Maximum cross–sectional area (sq in.)	Side area (sq in.)
213	6	14,831	4540	226	1639
203	9	12,916	4581	182	1752
214	12	11,528	4654	150	1870
224	15	10,653	4760	130	1985

The models were mounted on a single support strut for testing, as
shown in figure 3.

The tests were made in the Langley 300 MPH 7– by 10–foot tunnel at
a dynamic pressure of 100 pounds per square foot, which corresponded to
an airspeed of about 200 miles per hour. The Reynolds number, based on
the mean aerodynamic chord of the wing of the hypothetical flying boat,
was about 2.5×10^6. The corresponding Mach number was about 0.22.

The hulls were tested with the transition fixed by a $\frac{1}{2}$-inch-wide
strip of 0.008-inch-diameter carborundum particles located approxi-
mately 5 percent of the hull length aft of the bow.

CORRECTIONS

Blocking corrections have been applied to the hull data. The drag
of the hulls has been corrected for horizontal buoyancy effects caused
by a tunnel static-pressure gradient. The effects of the support strut
which were determined by using an image system have been subtracted
from the data.

RESULTS AND DISCUSSION

The effect of length-beam ratio on the aerodynamic characteristics
in pitch of the hulls are presented in figure 4. A comparison of these
data with the data obtained in reference 1 for hulls with wing interference
indicates that the minimum drag occurs nearer zero angle of attack,
0° to 2°, for the hull alone. This effect might be expected since the
support wing used in reference 1 had considerable camber and was set
at 4° angle of incidence, which tends to give body minimum drags at
positive angles of attack (reference 3). The hull-alone data showed
about the same variation of pitching-moment coefficient with angle of
attack as was shown for the hulls with wing interference. Smaller values
of lift coefficient were obtained for the hull alone than were obtained
for the hull with wing interference. An increase in the length-beam
ratio decreased the minimum drag coefficient and slightly increased the
longitudinal stability. This effect is shown in figure 5 where a
comparison is also made of the minimum drag coefficient $C_{D_{min}}$ and the
stability parameter C_{m_α} for the hulls alone and hulls with wing
interference. The minimum drag coefficients for the hulls alone are
consistently higher than those for the hulls with wing interference; the
longitudinal stability of the hulls is only slightly affected by the
wing interference. The relatively large increase in minimum drag was
to be expected since the results of reference 4 indicated that the
minimum drags of fuselages were lower by an amount approximately equal
to the drag on the support wing submerged within the fuselage. The
interference effect caused by the interaction of the velocity fields
in the fuselage and wing, in general, increases the drag coefficient;
however, the increase is small compared to the favorable effect of the
submerged wing.

The variation of minimum drag coefficient with length-beam ratio
is about the same for the hull alone as for the hull with wing
interference as reported in reference 1; that is, minimum drag coeffi-
cient decreased when the length-beam ratio was increased from 6 to 15.

This fact would indicate, therefore, that the comparative drag coeffi-
cients of other hulls (reference 2), although representing a value
lower than the hull-alone value, should indicate the relative merits
of the various hulls. The values presented in references 1 and 2 are
representative only for a flying boat having a wing very similar to
the support wing used in those investigations, and any other wing
either thinner, less cambered, or with sweep is expected to give different
values of minimum drag coefficient and is also expected to present similar
trends with hull modifications. In order to indicate the relative
efficiency of the length-beam-ratio series hulls, the minimum drag
coefficients based on the wetted area of the hull $C_{D_{W_{min}}}$ have been

compared in figure 6 with theoretical values of $C_{D_{W_{min}}}$ for streamline

bodies, as given in reference 4. In order to obtain a more nearly
comparable value of fineness ratio than is indicated by length-beam
ratio, the fineness ratio of the hulls was calculated by using the
ratio of the diameter of a circle with an area equal to the frontal area
of the hull and the over-all length of the hull (the distance from the
fore perpendicular to the aft perpendicular). In this comparison the
skin area of the equivalent body is less than that for the actual hull.
The comparison in figure 6 shows that a large percentage of the drag of

the hull with $\frac{L}{B} = 6$ (fineness ratio, 6.5) was caused by form drag

because the theoretical drag was largely skin friction. The form drag
becomes a smaller part of the total drag as the fineness ratio increases.
The trend of the two curves indicates that some reduction in hull drag
coefficient might also be expected for hulls of larger length-beam
ratio than presented herein.

CONCLUSIONS

    The results of an investigation made to determine the effect of
increasing the length-beam ratio on the aerodynamic characteristics
of flying-boat hulls without wing interference and a comparison of
the results with results previously obtained for hulls with wing
interference indicated the following:

    1. The minimum drag coefficient decreased when the length-beam
ratio was increased from 6 to 15 in a manner similar to that indicated
for hulls with wing interference.

    2. The minimum drag coefficients were consistently higher than
those obtained with wing interference.

3. The minimum drag for all hulls tested generally occurred in the angle-of-attack range of about 0° to 2°.

4. The longitudinal stability of the hulls was only slightly affected by the wing interference.

Langley Memorial Aeronautical Laboratory
    National Advisory Committee for Aeronautics
        Langley Field, Va., May 18, 1948

REFERENCES

1. Yates, Campbell C., and Riebe, John M.: Effect of Length-Beam Ratio on the Aerodynamic Characteristics of Flying-Boat Hulls. NACA TN No. 1305, 1947.

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4. Young, A. D.: The Calculation of the Total and Skin Friction Drags of Bodies of Revolution at Zero Incidence. R. & M. No. 1874, British A.R.C., 1939.
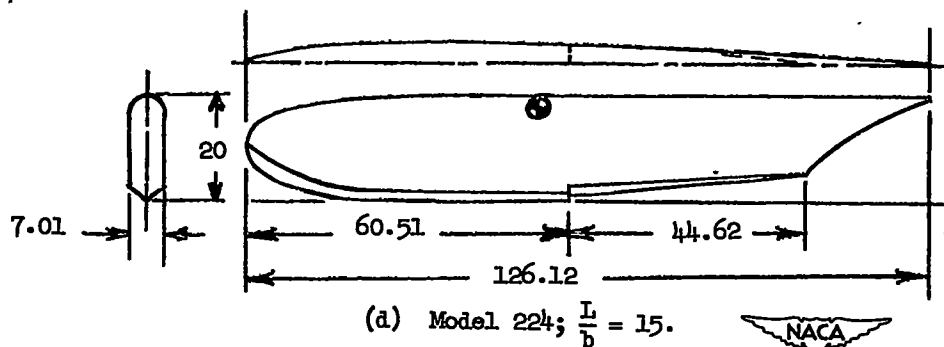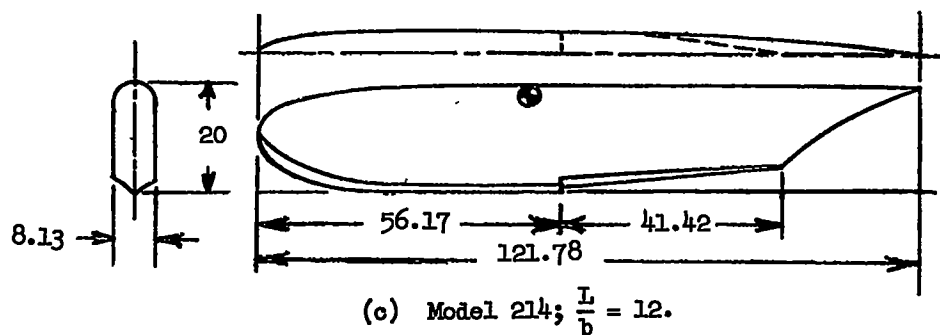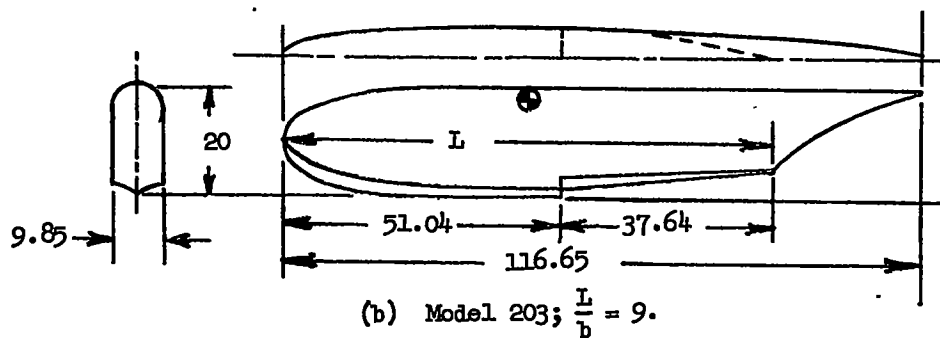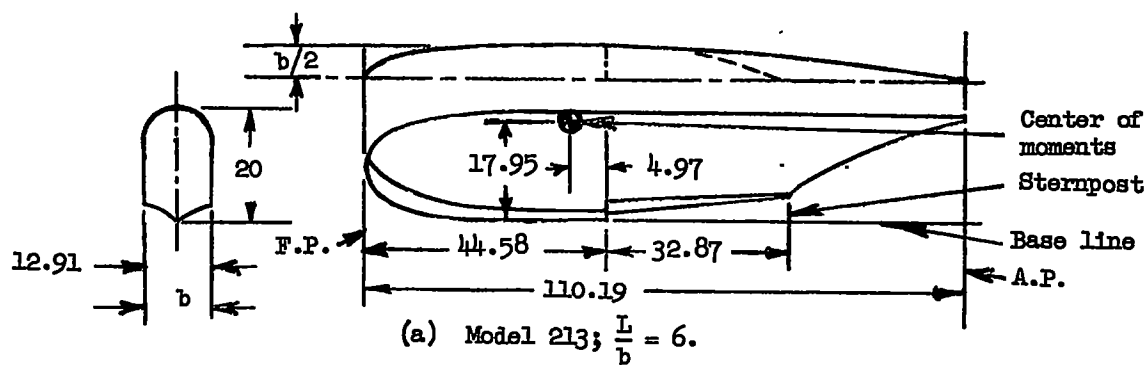
Figure 1.— Lines of Langley tank models. (All dimensions are in inches.)

Figure 2.- System of stability axes. Positive directions of forces, moments, and angles are indicated by arrows.
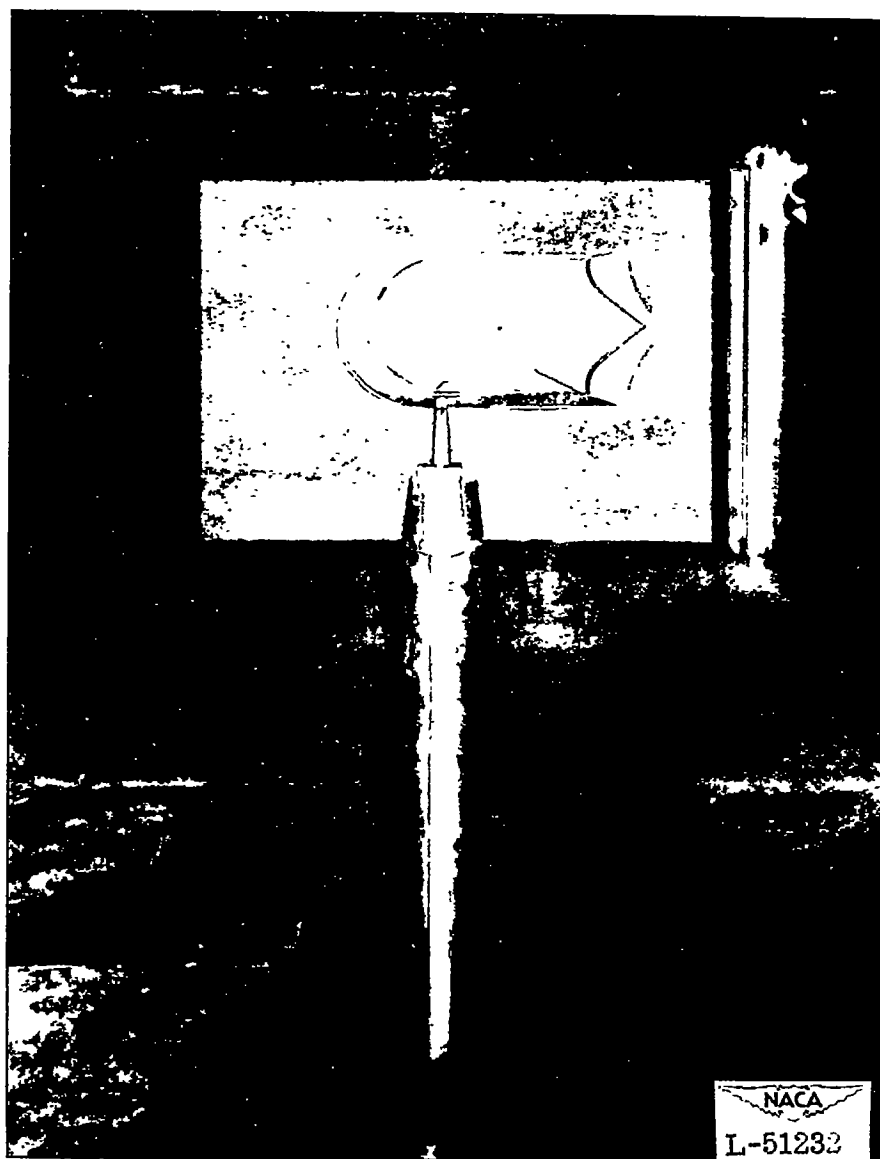
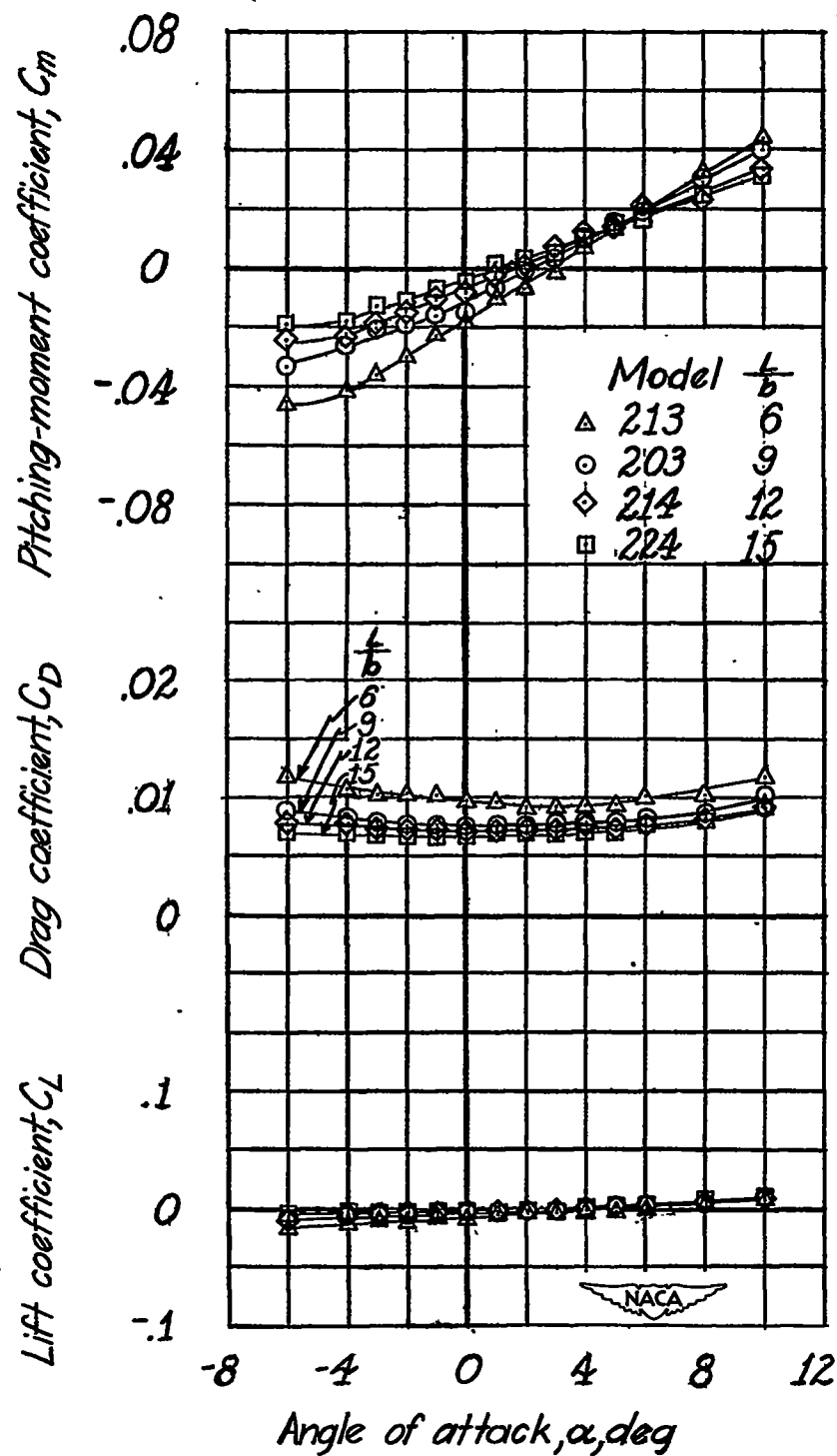Figure 3.- Hull mounted on single support strut in Langley 300 MPH 7- by 10-foot tunnel.

Figure 4. — Effect of length-beam ratio on aerodynamic characteristics in pitch of $\frac{1}{10}$-scale hulls of hypothetical flying boat.
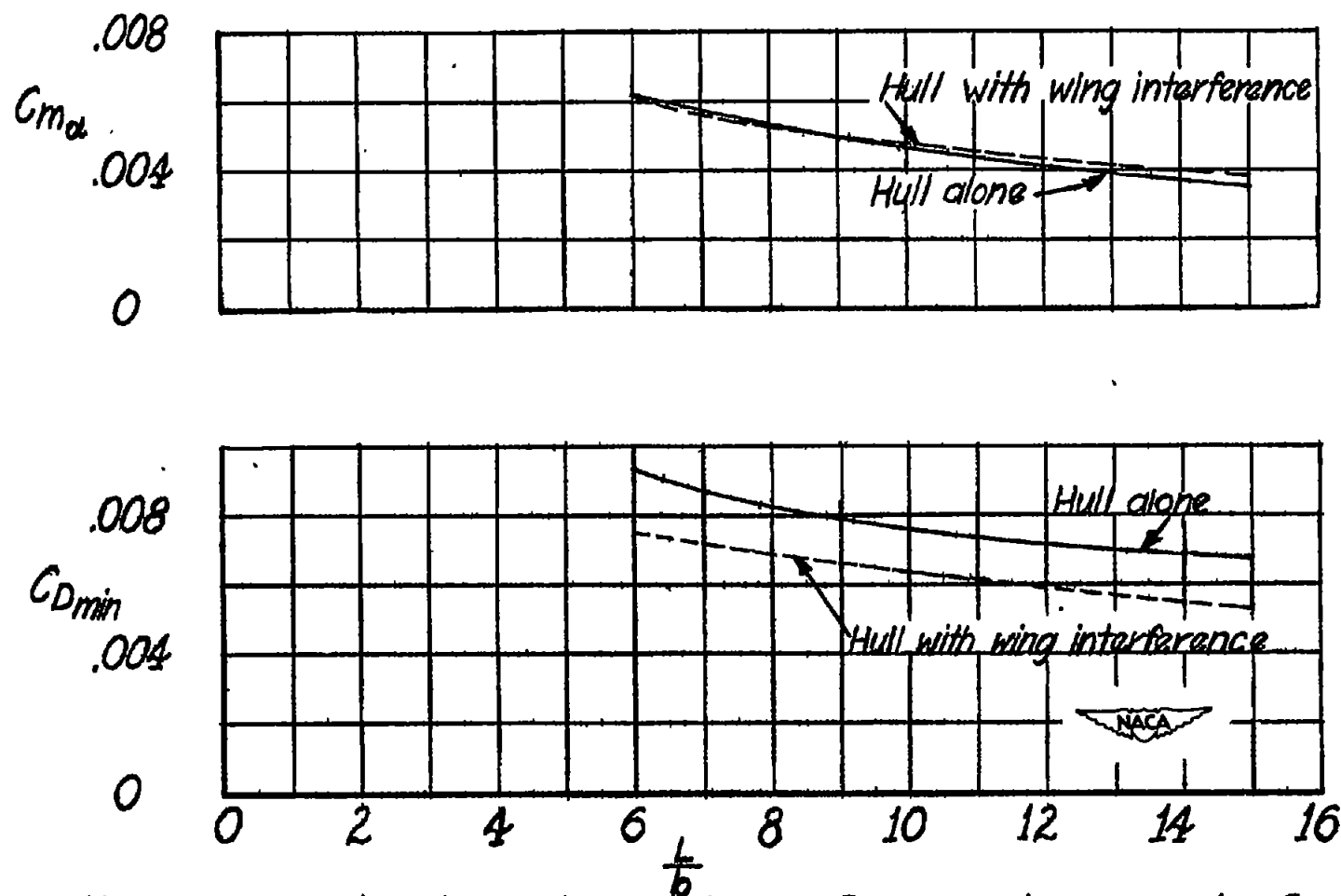
Figure 5.- Effect of length-beam ratio on $C_{D_{min}}$ and parameter C_{m_α} for the $\frac{1}{10}$ -scale hulls of a hypothetical flying boat.
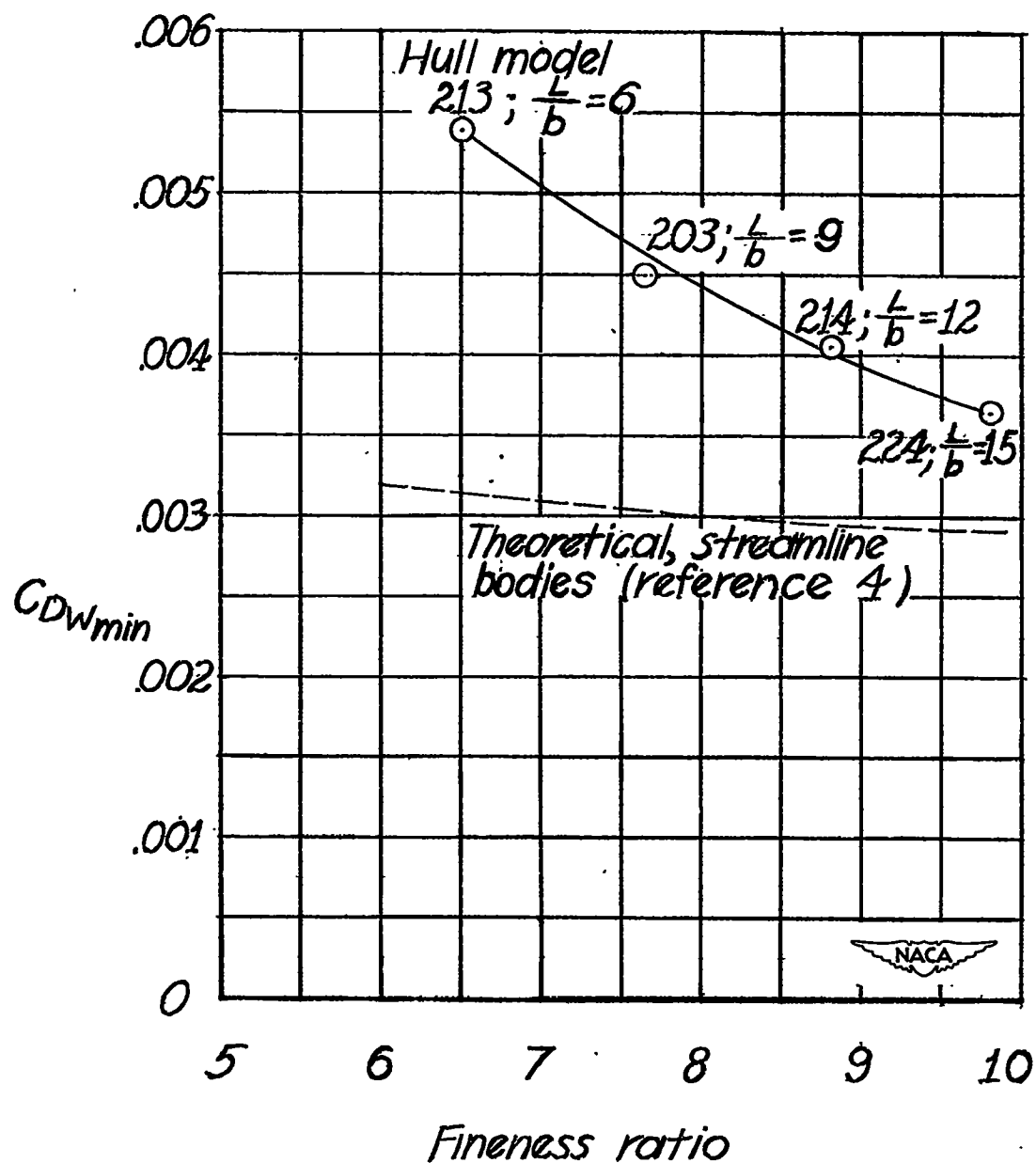
Figure 6 .- Comparison of theoretical drag coefficients of streamline bodies with experimental drag coefficients of flying-boat hulls with length-beam ratios of 6,9,12,and 15.